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Twin Rotor Turbopump Program
Contract NAS8-97161

Progress Report
10 March 1997 through 30 April 1997
Data Item 832MA-002

Prepared for National Aeronautics and Space Administration
George C. Marshall Space Flight Center
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Introduction:
NASA Marshall Space Flight Center (MSFC) has committed its resources to develop the Bantam System Technology Program. This initiative seeks to demonstrate technology applicable to low-cost, innovative, and unique rocket system payoffs for the next generation rocket propulsion systems. One component of this project is the MSFC Ablative Engine. The objective of the Ablative Engine Program is to demonstrate low-cost hardware using low part count design, commercial off-the-shelf (COTS) materials, and low cost fabrication methods. Pratt & Whitney's Twin Rotor Turbopump (TRT) program will produce a demonstrator of an alternative turbopump configuration for the MSFC Ablative Engine.

The TRT is a liquid oxygen/kerosene (LOX/RP-1) turbopump that incorporates two similar counter-rotating rotors in a back-to-back configuration. These one-piece rotors have integrally bladed propellant impellers and drive turbines, and are supported by hydrostatic bearings. The rotors are housed in two similar housings, which are assembled back-to back. The configuration is shown in Figure 1.

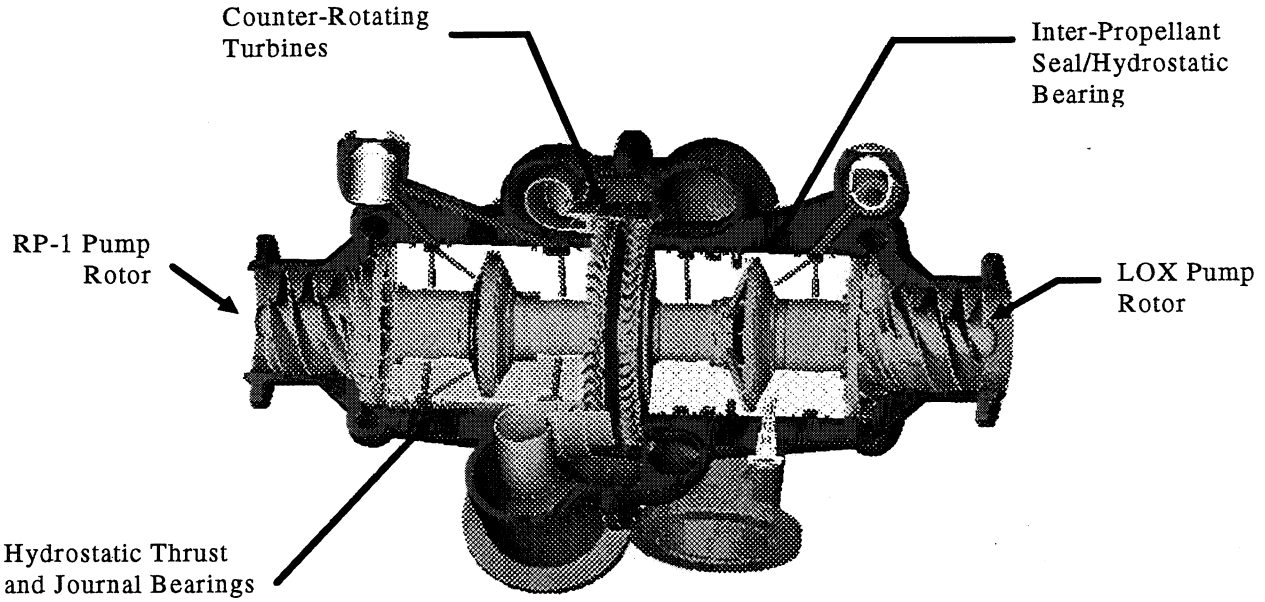


Figure 1. Twin Rotor Turbopump Configuration

The program consists of five tasks: (1) project direction; (2) systems engineering; (3) turbopump design; (4) hardware fabrication; (5) hardware assembly and delivery

Task 1 - Project Direction:
Authority to proceed (ATP) was received from NASA-MSFC on 10 March 1997. An Integrated Product Team (IPT) was formed, with representatives from P&W Engineering and Operations, and the

Customer. The first IPT meeting was held on Wednesday, 19 March 1997. A program schedule based on the ATP date was established. The schedule is shown in Attachment 1.

A Product Definition Briefing as required per SOW paragraph 3.1.2.3 was scheduled for 1 May 1997.

Task 2 - Systems Engineering:

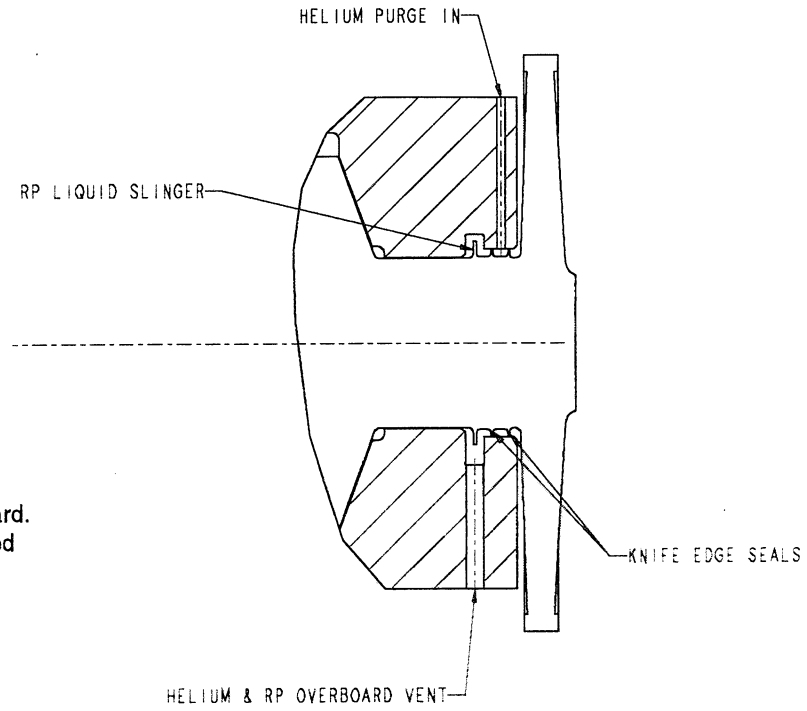
A preliminary design table has been established for the TRT. The table is based on the pump and turbine flow conditions established for the TRT per the Contract Statement of Work., and supplemented by secondary flow conditions generated by P&W's design codes. The design table for the TRT is shown in Attachment 2. Discussions with NASA-MSFC personnel regarding turbopump instrumentation and the test plan are underway. Preliminary recommendations will be presented at the Product Definition Briefing.

Task 3 - Turbopump Design:

The primary focus of the turbopump design task for this reporting period was to confirm the conceptual design and begin aerodynamic (turbine), hydrodynamic (pump) and bearing component design activity. Trade studies involving turbine vs. pump speed for each rotor, and speed optimization between the back-to-back turbines were carried out. Although a goal of the proposed design was to use identical rotors for the RP-1 and LOX pumps, the detailed design activity carried out in this period indicated that the pump and turbine performance requirements could not be achieved with identical elements. However, the same material is still used for both rotors, and the size and arrangement of the pump, bearings, and turbine elements are similar, so common raw material and/or forgings can be used for fabrication. The key features of the conceptual design, which are the use of hydrostatic bearings and the back-to-back counter-rotating turbines, have been maintained.

During the 1 April 1997 IPT meeting, NASA indicated the turbopump would have to tolerate a LOX-rich turbine drive fluid during the start transient. A helium purge feature was added to the cavity between the RP-1 pump turbine and the bearing. Helium supplied to this cavity will isolate the turbine from the RP-1 ventage fluid during the start cycle. After start, the helium purge can be turned off (via an test stand- or engine-supplied valve) to reduce helium consumption. The purge feature is shown in Figure 2.

Another major activity occurring during this reporting period was contracting with Parametric Technologies Corporation (PTC) to assist P&W's design department in setting up a design system based on their Pro/E program. Pro/E is a commercially available software package that offers a high degree of synergism between the mechanical design models, the models used for component design and analysis, and generation of drawings and a configuration management system. Pratt & Whitney has set up this system for the TRT to facilitate the low-cost design goal and the aggressive program schedule.



- During LOX rich start transient, the overboard vent is open and the helium purge is on. RP coming from the bearing is vented overboard.
- During steady state operation, the vent is closed and the RP is allowed to dump into the turbine flowpath. Helium purge is off.

Figure 2. RP-1 Turbine Helium Purge Feature

Task 4 - Hardware Fabrication:

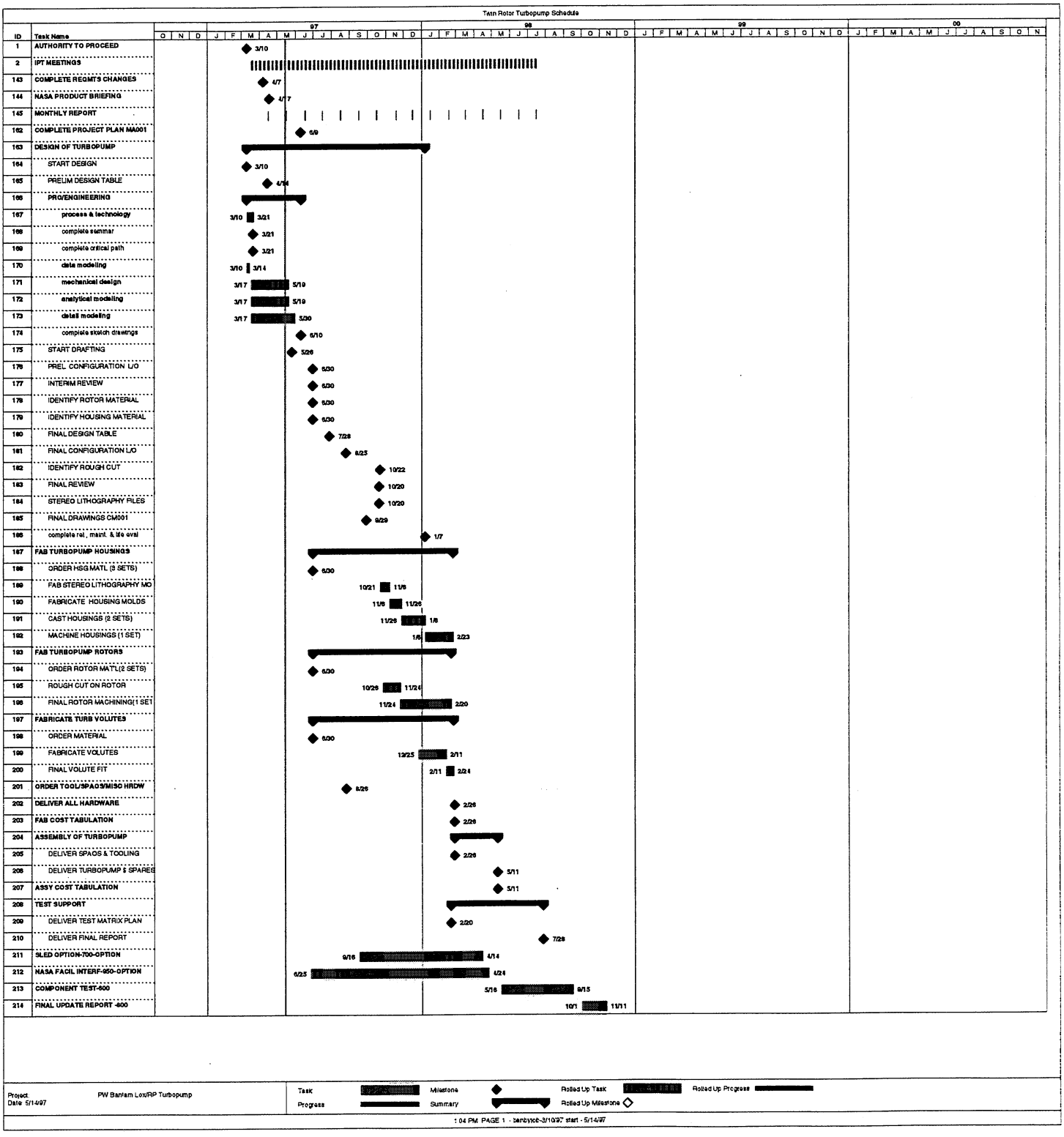
Dialog with suppliers identified during the conceptual design and proposal phases of the program was resumed. The listing of potential suppliers has been reduced based on their capabilities to produce hardware within the program cost and schedule goals. Potential suppliers for the major components are being asked to produce revised bids to allow P&W to finalize the supplier selection so the selected suppliers can participate in the final design effort. The suppliers still under consideration are listed in table 1.

Component	Supplier
Rotors	Dynamic Engineering, Newport News, VI Machine Specialties, Inc. - Greensboro, NC Paragon Precision - Valencia, CA
Bearings	Machine Specialties, Inc. - Greensboro, NC Micro Craft, Tullahoma, TN Stein Seal, Kulpsville, PA
Housing (Castings)	Soligen - Northridge, CA Precision Castparts Corp. - Portland, OR Wyman Gordon Investment Casting - Groton, CT

Table 1. Suppliers Under Consideration For Major TRT Components

Task 5 - Hardware Assembly and Delivery:
Assembly activity is not scheduled to start until CY1998. The Rocket Assembly area is represented in the IPT.

Attachment 1



Attachment 2 - Design Table for the Twin Rotor Turbopump

Pump Performance Characteristics	RP-1	LOX
Delivered Flowrate, lb/s	***64.3***	***139.3***
Inlet Pressure, psi	***28***	***46***
Exit Pressure, psi	***960***	***919***
Inlet Temperature, R	***530***	***166***
NPSH Ava., ft	73.3	56.9
Total Pump Flowrate, lb/s	71.7	152.6
Exit Temperature, R	537	171
Efficiency	68	66.5
Power, Hp	510	740
Speed, RPM	16,800	22,000
Specific Speed	1150	2500
Head Rise, ft	2670	1780
Exit Diameter, in	5.6	4.1
Tip Speed, ft/s	414	394
PE Bearing Flow, lb/s	2.7	7.7
TE Bearing Flow, lb/s	1.2	(He .04)
Thrust Bearing Flow, lb/s	3.5	2.9

Turbine Performance Characteristics	RP-1	LOX
Flow Rate, lb/s	***7.1***	***7.1***
Inlet Pressure, psi	***540***	***210***
Exit Total Pressure, psi	***210***	***66.1***
Inlet Total Temp., R	***1600***	***1477***
Exit Static Pressure, psi	151	47
Efficiency (T/T)	61.2	74.3
Efficiency (T/S)	45.8	58.7
Pressure Ratio (T/T)	2.52	3.18
Pressure Ratio (T/S)	3.50	4.43
Power, Hp	510	740
Speed, RPM	16,800	22,000
Inlet Mean Dia, in	9.45	9.58
Max Tip Speed, ft/s	705	960
$AN^2 \times 10^8$	24	61
U/C, actual	.422	.467
Gas Constant, ft-lb/lb-R	45.8	45.8
Gamma	1.108	1.108
Exit Rel. Mach No.	1.35	1.36
Exit Absolute Mach No.	0.78	0.78

Note: Parameters in italics reprsent requirements per tables 1 and 2 of the Contract SOW.